

# Functional Relationships

- Specification of functional relationships among ecosystem components is an essential precursor to the development of predictive ecosystem models in support of management. In essence, we are trying to reverse engineer the ecosystem to understand its structure and function.
- Determining the nature of functional relationships among ecosystem components will rely on evaluation of time series information, adaptive management experiments, and other approaches.
- Ecosystem considerations include the specification of the functional forms of bottom-up and top-down forcings in system dynamics.
- Incorporating the increased dimensionality accompanying ecosystem considerations results in changes in management reference points.
- This increase in dimensionality increases some aspects of uncertainty in predicted outcomes and the probability of complex dynamics including the possibility of alternative stable states.
- The need for risk assessment and the application of the precautionary approach is clear.

## Functional Relationships: empirical aspects

- While we cannot conduct controlled ecosystem-level replicate studies, the prospects are good for learning about ecosystem control mechanisms from inter-system comparative studies as well as from intra-system time series studies;
- Evaluation of functional relationships for key components of an ecosystem may be facilitated using statistical approaches to guide formulation and parameterization of ecosystem-level models;
- Testing of ecosystem models is currently focused on fitting to time series data using log likelihood criteria while evaluating the relative impact of multiple drivers (climate, nutrient loading, habitat modification and fisheries);
- Related activities are in progress worldwide, including at several NOAA agencies and councils. Results indicate that most ecosystems are impacted by multiple drivers;
- Formal evaluation of how assumptions about functional relationships impact the predictive capabilities of ecosystem models for fisheries management is required;

## **Functional Relationships: empirical aspects**

- Evaluation requires information over long time periods as data-contrast is essential to test alternative hypotheses for functional response formulations;
- Such testing calls for back-calculation, and typically requires expanding time series of abundance and fishing pressure for multiple ecosystem components, including for non-commercial species – this calls for concerted data scavenging activities;
- Application of multiple modeling tools testing different functional relationships should be encouraged;
- Ecosystem modeling approaches should be designed to give reliable directional guidelines as part of a strategic management approach; this may best be performed as part of an adaptive management scheme;
- Testing alternative hypotheses may call for adaptive management experimentation, notably where time series information shows little contrast. Examples include using closed areas, varying exploitation rate, production through stock enhancement, habitat modification using artificial reefs, oil rigs, etc.

## Functional relationships: bottom-up forces

- For purposes of EAF discussion, bottom-up forces = forces that drive system productivity
- System productivity: basis for energy flows and carrying capacity; determines what/how much we can extract
- Interacting physical, chemical, biological forces; some are anthropogenic
- Physical forces
  - Light, temperature influence photosynthesis, other metabolic rates
  - Circulation, upwelling affect nutrient delivery and residence times; retention and dispersal of plankton, larvae
- Chemical forces
  - Nutrients (N, P, Si, Fe) facilitate or limit primary production and blooms
  - Nutrient ratios can lead to different compositions of phytoplankton, blue-green algae, etc.
  - Dissolved oxygen: hypoxia or anoxia may cause mortality, alter spatial distributions, disrupt linkages

## Functional relationships: bottom-up forces

### Biological forces

- Food abundance and patchiness influence foraging behaviors, growth rates of higher consumers
  - Food quality influences growth, allocation of energy to reproduction
- System-level carrying capacity: ultimate limit on how much can be sustained via different trophic pathways

### Human impacts

- Eutrophication increases production, but possibly of inedible and/or nuisance primary producers
- Habitat degradation: removes refuges, spawning habitat, juvenile nursery area, prey aggregation sites
- Human-mediated climate change may shift production regimes, species distributions

Stochasticity: climate anomalies & regime shifts change carrying capacity by altering temperature, circulation, etc.

Multiple interactions: >1 factor may co-occur, producing non-linear dynamics, unexpected results

# Top Down Mechanisms: Predation and Competition

- Humans are part of the ecosystem – we are predators and competitors
- The functional feeding responses of predators strongly affects the stability properties of the system
- A common framework exists for viewing humans as predators through optimal foraging theory
- Fishing can exert indirect effects by changing trophic structure
- Fishing can alter the outcome of a competitive interaction?
- Critical understanding can be attained through evaluation of time-series (i.e. consumption etc)
- Determining types of systems where predation or competition is most or least likely to be an important mechanism
- Determine systems where competition is most or least likely to be an important mechanism
- Are certain life history stages more important than others?

## Implications for Reference Points

- Broadening the scope of management to encompass ecosystem considerations fundamentally changes our perceptions of human impacts and the interplay between humans and ecosystem dynamics. EAFM addresses issues that FM does not.
- Low frequency changes in the biotic and abiotic components of the environment can result in the need to fundamentally adjust management strategies. The possibility of synergistic interactions between harvesting and environmental change must be recognized.
- Human alteration of habitat as result of fishing activities fundamentally alters the shape of the production function, the optimal harvesting level, and rate of recovery of overfished species.
- In a multispecies setting involving technical and/or biological interactions, setting reference points will entail an explicit consideration of tradeoffs in yield and productivity of different species
- The interplay of changes in environmental forcing, habitat alteration, and technical and biological interactions increases the possibility of complex system dynamics including alternate stable states.

## FRs, Uncertainty, and Risk

- Risk assessments not often done, especially in ecosystem context. Tools are just being developed, but there's proven value in both complex quantitative models and simple qualitative ones.
- FR is in many ways the multi-species S-R equivalent: where ecology comes in; highly sensitive; require contrast to be elucidated; subtle differences in functional form hard to distinguish but influential.
- Like S-R we won't be able to predict functional responses anytime soon. Instead need to characterize and express uncertainty. Also valuable to identify factors that make models dangerous/unstable.
- Risk performance measures are good tool, can be stand-alone, additions to other PMs, or both. Ground them for decision-makers.
- Stock assessment approaches are inside view, will underestimate risk. Meta-analysis is a good compliment.
- Ideally derive PDFs around key streams for calculating risk, but can also do scenario analysis—crossing management and operational models.
- Will almost certainly find that, as is the case in S-S models, risk is manageable but with trade-offs in other performance criteria.